OPTIMAL MANAGEMENT OF CONFLICTING SPECIES: GREY SEAL (*HALICHOERUS GRYPUS*) AND ATLANTIC SALMON (*SALMO SALAR*) IN THE NORTHERN BALTIC SEA

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ABSTRACT

In the Baltic Sea, the successful conservation of grey seals has increased seal-induced damages to the Atlantic salmon fishery. The paper addresses the conflict between the conservation of the formerly endangered species and professional fishermen whose livelihood is also regulated by fisheries management. We develop a bioeconomic model that accounts for the age-structure of Atlantic salmon and grey seal populations. In order to reach a social optimum, we maximize the discounted net present value taking into account the seal-induced losses through a damage function. The socially optimal salmon stock size, salmon catch and fishing effort is studied under different management schemes aimed at mitigating the seal-salmon conflict. The results suggest that technological adaptation would effectively reduce the cause of the conflict, while a technology subsidy encouraging such adaptation shifts the economic responsibility from individual fishermen towards a broader public.

INTRODUCTION

A worldwide public concern is caused by recently emergent human-wildlife conflicts, which arise when a wildlife species and human compete for the same limited resource e.g. game species, crops or fish stocks. [1,2]. A special case of conflict occurs when a legally protected species affects resource user's welfare as a result of successful species conservation. Thus, conservation goals and economic use of resource can easily conflict, when the interest of society and private firms clash. On one hand society may perceive a mere overlap of species conservation and resource use, since it values both, whereas private firms may perceive a negative externality caused by the of society aiming for conservation.

In the Baltic Sea, the successful conservation[i] of the formerly endangered grey seal (*Halichoerus grypus*) is argued to affect the profitability of fisheries through seals damaging the fish catch to an extent that fishermen claim it to threaten their livelihood [3,4,5]. In 2009, seal-induced catch damage in terms of catch taken from the fishing gear was minimum 21 tonnes of salmon (*Salmo salar*) [6].

Our objective is to analyse the economic effect the grey seal population can have on the professional Finnish trap net fishery of salmon in the Northern Baltic Sea. We discuss and analyse the seal-induced changes and their effects on the profitability of the Finnish coastal trap net fishery. We contribute to the existing literature by applying a bioeconomic analysis, which provides new insights into the economics of the seal-salmon conflict. We also consider the technology subsidies used for mitigating the conflict by promoting a change towards using seal-safe trap nets. This mitigation measure shifts the economic responsibility from individual fishers coping with the seal abundance towards a broader public willing to preserve seals.

Seal-fishery conflict

Seals affect the fisheries directly in terms of interfering with the fishing activity by taking fish from the fishing gear, or leaving remains of half-eaten fish. This means that fishermen get smaller catches due to the interaction with seals. These seal-induced catch losses comprise 92 % of total salmon discards, showing that seals are the main cause of discards. The number of catch losses has been decreasing, mainly because the low profitability of the fishery has driven down the fishing effort. However, the gear choice makes a difference, since in experiments conducted 2003 and 2004, the catch from seal-safe pontoon trap nets accounted for 1 % seal-induced damages, whereas 54 % of the catch from traditional trap nets was damaged by seals [4].

Findings from technical studies [4,7,8] suggest that the gear-type as is strongly associated to the catch damage frequencies, which can be effectively mitigated by using a seal-safe gear called a pontoon trap net [14]. Clearly, potential for technology development exists, since only about one third of the salmon trap nets in 2009 were the seal-safe type in the Finnish professional fishery [6]. What makes this technical solution even more preferable is that it contributes to the protection of salmon and seal, because it allows for live-capture and release of naturally breeding mature fish [11], and prevents seals from drowning in the fishing gear. Fishermen willing to invest on seal-safe fishing gear are also provided with a technology subsidy covering maximum 15 % of the gear purchase price [15].

Despite advances in understanding both the role of technical solutions in reducing seal-induced catch losses (see e.g. [7,8,4]) as well as in the political aspects of the conflict mitigation in the Baltic Sea (see e.g. [9,10,11,5]) there has been little attempt to discover the economic aspects of the conflict in the marine setting. However, terrestrial human-wildlife conflicts have been addressed more thoroughly, and clearly, many characteristics from the terrestrial system can be found in the marine environment likewise [12,13].

The bioeconomic literature on the Baltic salmon fishery highlights the role of the trap net fishery and suggests considerable benefits from international cooperation in management [16,17,18,19]. So far the bioeconomic literature has focused solely on salmon, whereas our approach brings the bioeconomic theory of human-wildlife conflicts into the marine setting. We introduce a damage function approach to track the trade-offs between seal conservation and resource use, while quantifying the resulting economic losses caused to salmon harvesting. To the best of our knowledge this is the first time this approach is used in empirical bioeconomic analysis regarding marine environment.

BIOECONOMIC SIMULATION MODEL

In our model we encompass the economic influence of seals on the Finnish coastal trap net fishery of Tornionjoki river salmon stock (Fig. 1). It is worth noting, that we only focus on economic seal-fishery interaction, which is expressed through the use of damage functions.

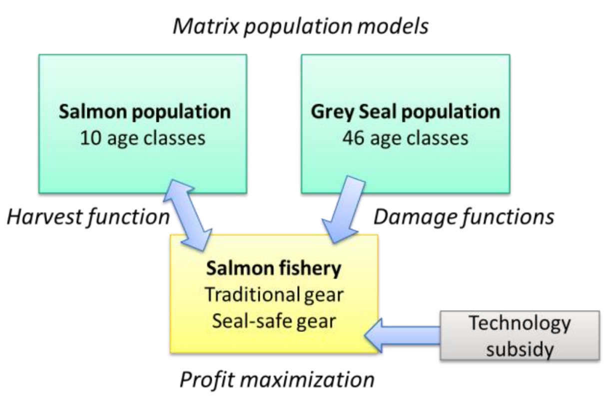

Figure 1. Model construction

First we develop age-structured discrete time deterministic matrix models to simulate the life cycles of salmon and grey seal [20]. For both species we use density-dependent growth. From the salmon population model we get ten age groups, from which the fishable sized ages are used as an input for the harvest function, where the harvest depends on the choice variable, the fishing effort, coupled with the catchability coefficient and age-specific homing rate, which defines the share of salmon heading to the spawning grounds. From the grey seal population simulation we get the number of seals, which is used in the damage function coupled with a damage parameter[ii] in defining the seal-induced catch losses. As the frequency of catch losses depends on the fishing gear, we use different forms of damage functions for traditional and seal-safe gear. For defining the damage function, we apply the functional forms used by agricultural economists in estimating yield losses [21].

Our model aims to find an optimal fishing effort, which maximizes the net present value of the salmon trap net fishery in presence of seals through the time period of 50 years. We formulate an objective function, where the profits of the salmon fishery depend on the catch price and harvest function, which is affected by the gear-specific seal damage function. Fishermen face gear-specific linear costs per unit of effort[iii]. The cost burden connected to the expensive seal-safe fishing gear can be diminished through a technology subsidy.

Results

Our results in Table I show that fishermen who use the traditional fishing gear suffer from high seal-induced catch losses. Even though the gear entails low fishing costs, the seal-induced damages are high enough to cause negative net present values after the 15th period. The seal-induced damages cover 16-27 % of the total catch before the fishery is closed due to negative income. These results may explain the continuous dispute over the grey seals and fisheries, since clearly seals do affect the profitability of the traditional trap net fishery.

Table I: Dynamic optimization results for traditional and seal-safe gear.

Gear	Summed net present value	Steady state effort in geardays	Seal-induced damages % of total catch
Traditional trap net	€106 100	0	16-27
Seal-safe trap net	€172 200	4733	0.18-0.3

If fishermen want to adapt to the presence of seals and avoid the catch losses, the best option is to use a seal-safe fishing gear. If the fishery switches to the use of seal-safe gear, the catch losses are close to zero, but the fishermen face high costs due to the expensive gear. Despite the high costs, the fishery remains profitable through time. The viability of the fishery implies that the fishermen are better off using the seal-safe gear in presence of seals comparing to using traditional gear.

Although according to our results fishermen are better off using the seal-safe gear than traditional gear, almost two thirds of fishermen still use the traditional gear. This lag in adapting to seal abundance is the reason why a technology subsidy is currently provided by the Finnish government as a conflict mitigation measure in order to encourage the use of seal-safe gear. To see how the subsidy affects the profitability of the fishery as well as the benefits and costs incurring to the society, we run the optimization model with different levels of technology subsidies.

The Finnish government pays a maximum technology subsidy of 15 % from the purchase price of seal-safe trap nets. By applying this level of subsidy, the net present value is almost double comparing to the case without subsidy (Fig. 2). The choice variable, fishing effort, increases with almost 2000 gear days. This seems very promising from the fishermen's point of view, however when we take into account the social cost burden of the subsidy, the effect is negative. This means that the total cost of subsidy is twice the profits derived from the fishery, which implies that the society as a whole generates only costs from keeping the fishery at this level.

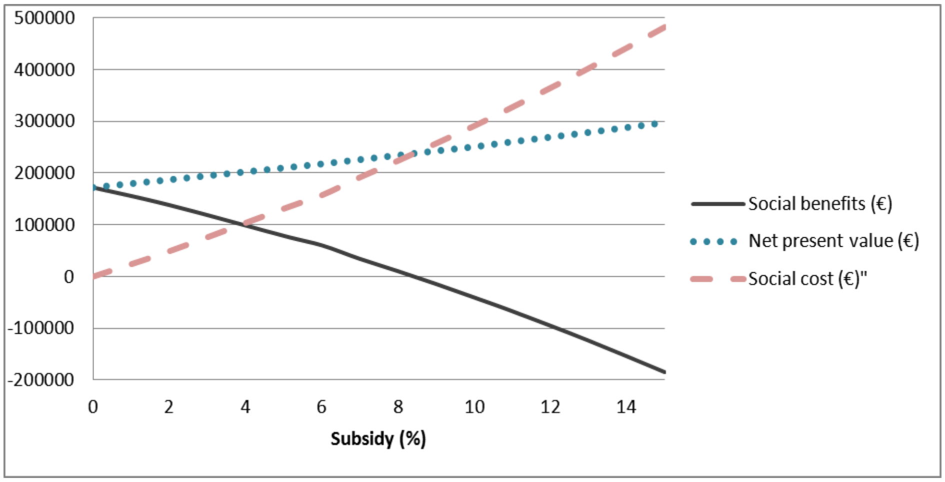

Figure 2. Net present value (dotted line), social benefits (solid line), and social costs (dashed line) according to the level of subsidy.

Figure 2 shows that the current level of subsidy is probably too high if we only consider the profits derived from the fishery and the cost of subsidy for the society. We can see that the society's benefits from paying a subsidy go negative when the subsidy level is about 8 %. At the same point the costs of subsidy become greater than the profits of the fishery.

CONCLUSIONS

The basis for our analysis is the notion that the ongoing conflict between salmon fisheries and grey seal conservation has been claimed to cause significant losses for the salmon fisheries, however studies on the actual economic effects have been absent. In order to study the economic effects of seals on trap net fishery, we developed a bioeconomic optimization model, which also allows analyzing current mitigation measures.

Our model results show that there are economic reasons to claim that fisheries suffer significant losses due to seals. However, our analysis suggests that by choosing the right gear, fishermen can avoid the losses caused by seals. While the low cost traditional trap net fishery ceases to exist, because high seal-induced losses make the fishery unprofitable, a viable fishery is reached through using the seal-safe gear. Our results suggest that the salmon fishery is viable in the long run only if the fishers are able to adapt to the high abundance of seals.

All in all, mitigating the conflict means to have a trade-off between social and private benefits. Subsidy is a way to compensate fishermen for living with the seals and to adapt to the co-existence, while this measure also shifts the economic responsibility to a broader public. Current subsidy level provided by the

Finnish government is high compared to the profits derived from the fishery, what may be an expression of the will to protect the small-scale professional fishing or it may reflect the social value of seals.

Regarding the social returns, society derives benefits not only from the fishery, but also from the seal conservation. The benefits attributed to seal existence remains unknown, although it is possible to get an estimation of the seal benefits with valuation studies. Improving the model by adding the seal benefits is a useful model extension, which enables a more complete view on the many-sided conflict.

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ENDNOTES

[i] Grey seals are listed in European Union's habitat directive annexes II and V. Annex II defines species which require the designation of special conservation areas. Annex V defines species whose exploitation may need management measures. (The Council of European Communities [2007].) Also an international agreement gives recommendations on the protection of seals under the Convention on the Protection of the Marine Environment of the Baltic Sea Area (HELCOM).
[ii] Damage parameter is calibrated from the reported seal-induced catch losses [3].
[iii] Fishing costs are calibrated to the Tornio river spawning stock.